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Acknowledgments

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Recommendations for Seedling Disease Control

1. KNOW YOUR PROBLEMS. There are several ways in which losses due to cotton seedling diseases can be reduced or eliminated. Be sure to know the cause of not getting and keeping a stand of cotton.

2. CROP ROTATION is necessary to prevent the build-up of certain cotton disease organisms in the soil. Where feasible, allow at least two years or longer between plantings of cotton on the same land. Select only fertile, well-drained, and warm-natured soils.

3. PREPARE SEEDBEDS early so crop residues can be disposed of properly. Deep plowing of cotton land may be desirable to break up hard pans and allow deeper penetration of cotton roots.

4. CHOOSE QUALITY SEED. Use the highest quality seed available. Know the origin and at least the percentage germination of cottonseed to be used for planting.

5. PLANT ONLY TREATED SEED. Use only treated cottonseed to help reduce losses from seed- and soil-borne disease organisms.

6. ONLY WHEN SOIL TEMPERATURES are high enough to give rapid germination and growth of seedlings should cottonseed be planted.

7. MAKE SURE that other factors, such as nutritional difficulties, nematodes, insects, and mechanical injuries, are not involved in stand losses.

8. USE SOIL FUNGICIDES at the time of planting *only* if a history of seedling disease due to soil-borne pathogens is known. Only certain fields and areas within fields may need to be treated. The use of a soil fungicide is good insurance for getting and holding a stand of cotton from the first planting where seedling diseases are a problem.

9. EARLY CROP RESIDUE DISPOSAL. Destroy cotton stalks immediately after harvest. This practice will reduce the amount of carry-over of certain cotton disease-causing organisms.

Cotton Seedling Diseases and Their Control

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Introduction

The purpose of this publication is to provide Louisiana county agents and cotton growers with the theory and practice of controlling the cotton seedling disease complex and to summarize research on cotton seedling diseases conducted by personnel of Louisiana Agricultural Experiment Station. Most of the research has been directed toward understanding and controlling cotton soreshin, caused by *Rhizoctonia solani* Kühn (*3*).[1] These data plus information from other workers are brought together to provide an up-to-date account of methods and materials involved in a program of controlling cotton seedling diseases for Louisiana.

I. The Problem of Cotton Seedling Diseases

Cotton seedling diseases are not new. The first report of *Rhizoctonia* sp. causing soreshin on cotton was made in 1895 by Atkinson (*3*) in Alabama. Edgerton (*31*) described the disease on Louisiana cotton in 1911. Only within the last decade, with costs of production increasing and profits decreasing, has the economic importance of soreshin and other seedling diseases of cotton gained recognition.

Losses due to cotton seedling diseases have led the list of estimated

TABLE 1.—Estimated annual losses, in per cent of cotton yield, as a result of disease damage in Louisiana for year indicated

	Year[1]			
Disease	1961	1962	1963	1964
Seedling diseases	5.0	5.0	5.0	5.0
Nematodes	1.0	4.0	5.0	5.0
Fusarium wilt	3.5	5.0	3.0	5.0
Verticillium wilt	1.0	1.0	1.0	0.5
Boll rots	5.0	10.0	1.0	30.0
Bacterial blight	Trace	0.5	Trace	Trace
Anthracnose	Trace	Trace	Trace	Trace
Ascochyta blight	Trace	Trace	Trace	Trace
Root rot	Trace	Trace	Trace	Trace
Total per cent loss	15.5	25.5	15.0	45.5

[1]1963 and 1964 estimates by J. A. Pinckard.

[1]Italic numbers in parentheses refer to Literature Cited, pages 33-35.

annual losses in cotton yield as a result of disease damage in Louisiana for the past 4 years (Table 1). Louisiana growers are not alone in this problem. Growers in Arkansas, Mississippi, Texas, and other cotton growing states suffer similar losses (*21, 22, 23, 24, 27, 30, 33, 54*). In 1961, 1963, and 1964 personnel of the Louisiana Agricultural Extension Service cooperated with the author in estimating per cent cotton acres

TABLE 2.—Summary on occurrence of cotton seedling diseases and use of soil fungicides for control of cotton seedling diseases, based on questionnaires completed by county agents in 1961, 1963, and 1964. (Approximate number of acres planted are given for 1963 and 1964.)

	Approx. No. acres planted		Per cent acres					
			Affected			Treated		
Parish	1963	1964	1961	1963	1964	1961	1963	1964
Acadia	10,000	11,000		25	60		5	1
Avoyelles	25,000	22,000	10	50	75	3	25	5
Bossier	20,000	18,000	100	75	60	25	30	35
Caddo	32,500	33,000	0	95	75	6	4	5
Caldwell	9,000			50			60	
Catahoula			65			35		
Claiborne	1,750	1,400	20	0	5	0	0	0
Concordia		9,700		60	15	3		20
De Soto		4,000		20	40	0		5
East B.R.	575			0			0	
E. Carroll	31,000	31,000	20	100	25	13	80	65
E. Feliciana	1,300	1,200		18	10		0	0
Evangeline	16,500	14,500	10	5	25	5	2	2
Franklin	60,000	60,000	90	20	40	6	8	10
Grant	4,636			50			30	
Iberia	400	400	10	0	20	0	0	0
Madison	23,000	23,000	95	2	10	50	40	50
Morehouse	35,000	34,000	80	90	100	40	65	20
Natchitoches	21,848		75		20	10	4	0
Ouachita		15,000	65		20	10		10
Pointe Coupee	8,000	8,000	80	50	50	20	37	30
Rapides	20,729		100	100		18	25	
Red River		10,200			15			45
Richland	50,600	53,981	60	40	75	5	15	5
St. Helena	500			10	0		0	0
St. Landry	34,500	34,000	25	10	20	10	5	15
Tangipahoa		600			10			0
Tensas	21,995	22,000	50	55	80	70	23	20
Union	3,300	2,700		10	2		0	0
Vermilion		3,000			50			0
Washington		3,000			15			0
Webster	2,500	2,500		0	0		0	0
W. Carroll	27,000	28,000	75	3	50	8	2	10
W. Feliciana	40			15			0	
Winn			100			25		
Other			35			18		
Total	461,673	446,181						
Ave. per cent			51	35	35	15	18	13

affected with seedling diseases (Table 2). Estimated losses, based on these figures and on observations of plant pathologists, ranged from 2 to 5 per cent of the potential yield in severely affected areas. Any individual grower may lose the equivalent of $\frac{1}{4}$ to $\frac{1}{2}$ bale per acre due to cotton seedling diseases when all factors (Fig. 1) are considered. In 1963, it was estimated that Louisiana cotton growers had a state-wide loss from these diseases of 5 per cent of potential yield, or about $6 million. In 1964 the estimated loss amounted to about $4 million. These estimates were based not only on number of plants lost to disease, but also on additional costs incurred because of an uneven, skippy stand and replanting. There are many factors in cotton production that are directly or indirectly influenced by seedling diseases (Fig. 1). Some of these factors include fertilizer use and costs, insect control, weed control, harvesting, and control of other cotton diseases. Studies for three years on three-quarter acre plots at the Northeast Louisiana Agricultural Experiment Station, St. Joseph, have shown that yield from replanted cotton has been consistently below that of nonreplanted cotton and cotton from soil treated with various fungicides (Table 3). The assurance of getting and keeping a uniform stand of cotton at first planting is one of the last problems to be solved before complete mechanization of cotton production can be realized.

Did You Have to Make This Choice Last Year?

Poor Stand Due to Seedling Diseases

Replanting	NOT Replanting
Additional seed	Plants not uniform
Additional wages	Skippy stand
Additional use of equipment	Loss of fertilizer
Loss of weed control chemical	Additional costs of weed control
Loss of soil moisture	Weak plants more susceptible to other diseases and insects
Late planting	Oil and flaming more difficult
Late harvest	Effect on mechanical harvesting
Additional insect control	
Increased boll rots	

FIGURE 1.—Many factors are involved where cotton seedling diseases are a problem.

TABLE 3.—Means for number of cotton seedlings per acre (stand) and yield of seed cotton per acre with various soil fungicides at a rate of three pounds per bushel of seed using the hopper-box method of application, for year indicated, Northeast Louisiana Agricultural Experiment Station, St. Joseph

Fungicide	Per cent active ingredient	1962		1963		1964	
		Stand	Yield	Stand	Yield	Stand	Yield
PCNB + captan	10-10	58,500	984*	35,500	766*	30,250	1,424
PCNB + OM-2424	10-10			46,750	768*		
PCNB + maneb	10-10	58,450	932*				
Nabac + captan	3-7					27,750	1,462
Nontreated check		45,500	982*	39,750	742*	28,000	1,576
Replanted nontreated check			737	34,500	427	29,500	1,402
LSD at .05 level		NS	24	NS	66	NS	NS

*Significant at .05 level.

II. Symptoms and Causal Agents of Cotton Seedling Diseases

"Cotton seedling diseases" is a term for a relatively complex situation that involves an interaction between various disease-causing organisms and the environment. Very few disease complexes have been studied (*46*). Pathogens, or disease-causing organisms, are carried in one form or another either on the seed or inside the seed (*15, 21, 53*), or they live over from season to season in soil (*2, 12, 21, 27*). The presence of pathogens associated with seed or soil often cannot readily be detected in the field until infected cottonseed, seedlings, or larger plants show symptoms of infection. The cotton seedling disease complex includes the diseases called seed rot, seedling root rot, and pre- and post-emergence damping-off (Fig. 2).

A. Seed Rot

A number of pathogens either in soil or associated with seed cause deterioration of cottonseed after planting (*1, 2, 10, 12, 19, 20, 21, 24, 30, 46, 47*). Maier and Staffeldt (*21*) isolated nine different fungi and a bacterium from nonsterilized, acid-delinted seed. Presumably these organisms were carried inside the seed, since acid delinting destroys organisms on the outside of seed. Soil-borne organisms that attack and destroy cottonseed develop rapidly when nontreated seed are planted in cool, wet soil. After a pathogen rots one seed, it moves to other seed and either completely or partially rots them. As a result both seedling stand and vigor are reduced. *Rhizoctonia solani, Fusarium* sp., and other soil saprophytes are involved (*21*).

Pathogenic organisms borne on nontreated seed also cause diseases of cotton seedlings or mature plants later in the growing season (*1, 4, 8, 15, 19, 53*). These are the organisms that cause Ascochyta blight (*Ascochyta gossypii* Syd.) (*19*); bacterial blight (*Xanthomonas malvacearum* (E. F. Sm.) Dowson) (*8, 15*); anthracnose (*Colletotrichum malvacearum* Southworth) (*1, 4*); and Fusarium wilt (*Fusarium oxysporum* f. *vasinfectum* (Atk.) Snyder and Hansen) (*53*). Control of cottonseed rot is discussed under seed treatment.

Seed deterioration can result from improper handling of seed cotton during harvest, from storing cottonseed under unfavorable conditions (*6, 7, 16, 17*), or from chemical changes in the seed (*6, 7, 16, 17*). Such seed have low viability and are more susceptible to seed-rotting organisms (*6, 7, 16, 17*). A discussion of this topic is presented in the section dealing with seed quality.

B. Pre-emergence Damping-off

Pre-emergence damping-off is used to describe a disease of cotton seedlings that appears between seed germination and emergence.

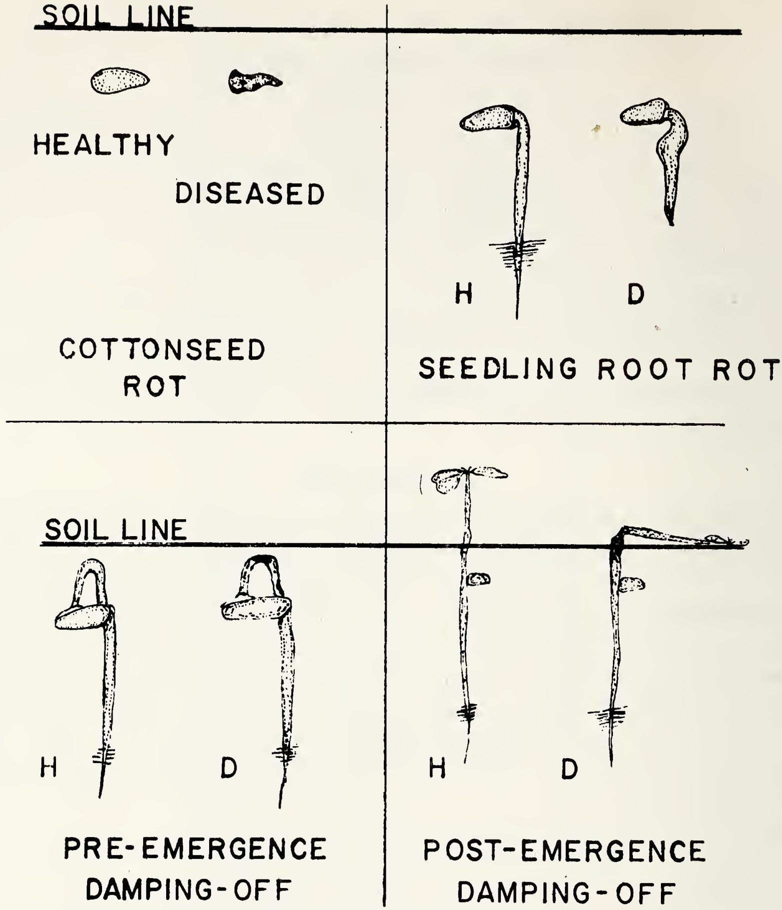

FIGURE 2.—Diagrammatic representation of four major phases of cotton seedling disease complex: seed rot; seedling root rot; pre- and post-emergence damping-off.

Symptoms are found on the newly formed root and are associated with root rot. The hypocotyl or stem also may be infected. Usually this latter type of infection is characterized by lesion formation at the crook of the hypocotyl, i.e., the first portion of the stem to emerge from the seed (Fig. 2). As the lesion continues to enlarge the stem is girdled. In either case, seedlings are killed or so weakened by infection that they cannot emerge. This results in reduced and uneven stands.

Both seed- and soil-borne pathogens cause pre-emergence damping-off. The soil-borne fungi *R. solani*, species of *Pythium*, *Fusarium*, and *Thielaviopsis* are the chief causal agents of this type of disease (*2, 5, 10, 12, 21, 24, 27*).

Control of pre-emergence damping-off is obtained through the use of seed and soil treatment. Both control measures are discussed in detail later.

C. Seedling Root Rot

Seedling roots might become infected any time after seed germination, but conspicuous symptoms and severe damage may not occur until after emergence of the seedling.

Several pathogens can cause cotton root rots, including species of *Fusarium, Pythium, Rhizoctonia,* and *Thielaviopsis* and other seed- and soil-borne organisms (*2, 5, 10, 12, 21, 24, 27*).

Symptoms of Fusarium root rot are a dry, dark-colored rot that progresses up the root and into the stem. These symptoms can be confused with post-emergence damping-off caused by *Rhizoctonia* sp. Pythium root rot is characterized by a light-colored, soft decay of the tap root and is most severe under very cool, wet conditions. *Rhizoctonia* sp. produces a dry, dark-colored rot over a wide range of conditions and is more important as a post-emergence damping-off organism. *Thielaviopsis* sp. causes a cortical rot which is brown to black. This fungus first rots tips of small feeder roots and then proceeds into the cortex of tap roots. The cortex of a diseased plant can be pulled away leaving the whitish stele. Only after isolation of the causal organism from diseased tissue can the pathogen involved be positively determined.

Environmental conditions, such as soil moisture and temperature and nutrients, have an important influence on incidence and severity of root rot infections. Seed and soil treatment, discussed in detail later, are means of controlling this phase of the seedling disease complex.

D. Post-emergence Damping-off

Symptoms of this disease appear at any time during the first part of the growing season (Fig. 2). A number of pathogens have been associated with this disease, including species of *Rhizoctonia, Fusarium, Pythium, Colletotrichum, Rhizopus, Aspergillus,* and *Penicillium,* and others (*2, 5, 10, 12, 21, 24, 27*). Isolations from diseased cotton seedlings collected from Louisiana fields showed that there were at least five fungi consistently involved (Table 4). Of these, *Rhizoctonia* sp. accounted for over half to three quarters of the infections.

R. solani incites the post-emergence damping-off disease of cotton called soreshin. Because this fungus is the most important one involved in seedling disease, many studies have been made on it by members of the L.S.U. Agricultural Experiment Station staff and will be reported here.

Plants infected with *Rhizoctonia* sp. under field conditions at first appear stunted and lighter green than normal. As the disease progresses, flagging (wilting at midday) becomes evident and lesions appear at or

TABLE 4.—The per cent occurrence of fungi isolated from diseased cotton seedlings collected at various locations in Louisiana for the year indicated

Fungus	Year 1962	Year 1963	Year 1964
Rhizoctonia sp.	51.5	66.4	28.2
Colletotrichum sp.	9.6	11.7	0.0
Fusarium sp.	8.0	5.8	30.6
Aspergillus sp.	5.3	5.8	0.0
Pythium sp.	1.1	2.2	15.3
Other (*Rhizopus* sp., *Diplodia* sp., and *Helminthosporium* sp., etc.)	24.5	8.1	25.9
Total	100.0	100.0	100.0

near the soil line on the hypocotyl or stem of the young plant. These lesions are at first light brown, changing to dark brown, then to black. As the fungus develops in the stem tissue, the infected area becomes collapsed and gives rise to a "wire-stem" appearance (Fig. 2). Under continued favorable conditions for disease development, infected plants topple over and die. Stands become uneven in height, skippy, and unthrifty.

Calcium deficiency may cause a collapse of the hypocotyl, yellowing and necrosis of cotyledonary leaves, and killing of the terminal growing point (*58*). These symptoms may be confused with those produced by fungus infection. If the plant survives, lateral roots are produced above the lesion and the plant does not have a tap root. This leads to the condition called "nub-root" in older cotton (*57*).

Penetration and infection of cotton stems by *Rhizoctonia* sp. takes place just before or after emergence. Symptom expression may be delayed depending on environmental conditions. Cool temperatures and abundant moisture are the two most important factors in disease development (*12, 13, 21, 30, 40, 41, 56*). Weather conditions favoring the growth of cotton, but not that of the fungus, can delay symptoms after infection; thus cotton seedlings infected in mid-April may not show severe symptoms until late May (*25*). Such cotton plants may continue to develop and outgrow the disease. Plants of this type, however, give rise to an uneven, unthrifty stand and may be damaged to such extent that, if infected plants survive, they are slowed down in their growth and become dwarfed when compared with noninfected plants. Such seedlings are more affected by thrips infestation (*26*) and other adverse conditions (*24, 35, 37, 38*). Cotton in a field with this condition can be severely damaged or killed when oil or flaming techniques are applied for weed control. These dwarfed plants, also, are more susceptible to damage by certain lay-by herbicides than are noninfected plants.

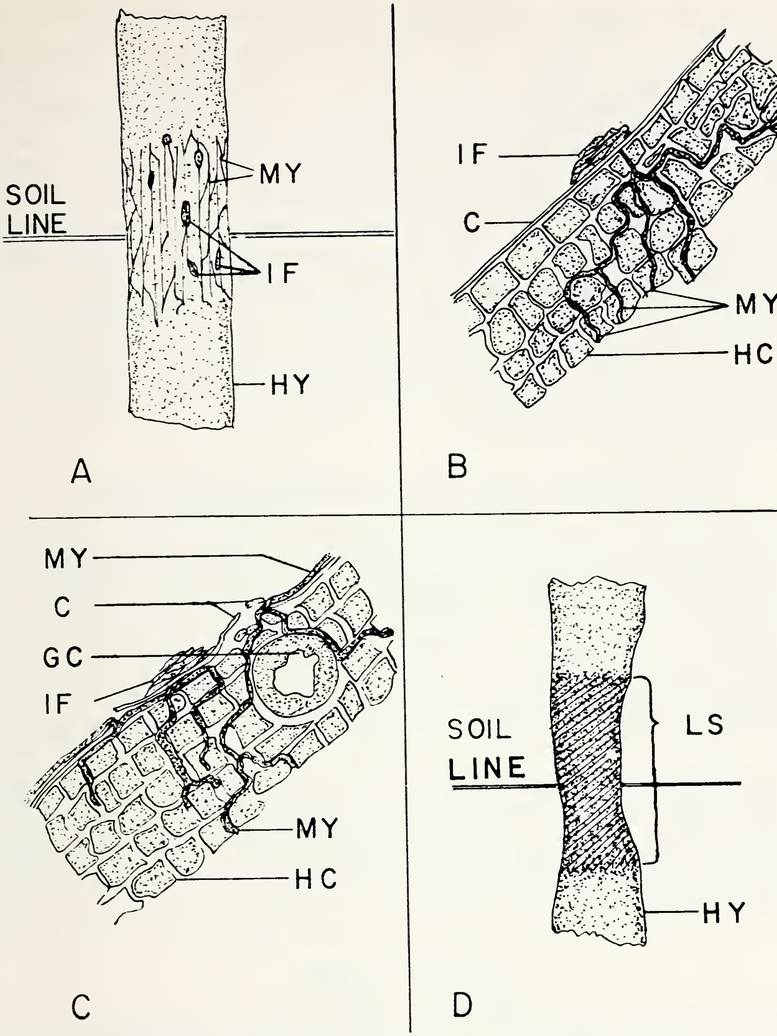

FIGURE 3.—Diagrammatic representation of penetration of and infection by Rhizoctonia solani Kuhn on cotton seedling hypocotyl. A) The fungus mycelium (MY) oriented itself longitudinally on hypocotyl (HY) and formed infection cushions (IF). B) Penetration of the host tissue by mycelium (MY) took place under the infection cushion (IF), through the cuticle (C); mycelium then grew between and through host cells (HC). C) The fungus mycelium (MY) penetrated without infection cushions (IF) where the epidermis and cuticle (C) of the hypocotyl had been opened by the enlargement of gland cells (GC) or injury. D) After initial penetration, the fungus grew into adjacent tissue both above and below the soil line and caused a conspicuous lesion (LS) on the hypocotyl (HY).

To better understand the infection process and development of the *Rhizoctonia* sp. fungus in the stems of seedling cotton, a study was made by Khadga, Sinclair, and Exner (*18, 52*). Using standard techniques, they made a microscopic examination of cotton seedling hypocotyls infected with *R. solani*. It was found that the fungus was able to penetrate mechanically the cuticle, epidermis, and first layers of cortical tissue. Penetration occurred beneath a specialized structure called an infection cushion (Fig. 3A). The infection cushion was formed by the intermingling of hyphae of the fungus. After penetration the fungus was able to grow between and through the cells of various plant tissues (Fig. 3B). It was found that within 48 hours after penetration, tissues about centers of invasion were completely disintegrated (Fig. 3C). After infection was established, the fungus continued to grow into adjacent plant tissue (Fig. 3D).

III. Control of Cotton Seedling Diseases

Control of cotton seedling diseases comes through the use of preventative measures rather than cure. Some plant diseases are controlled by the development of varieties resistant to the pathogen. At present the breeding for resistance to seedling diseases seems remote because of the variety of organisms involved in the complex (*2, 12, 21*), the variation in susceptibility to various isolates of *Rhizoctonia* sp. (*10, 21, 43, 44, 51*), and the lack of a high type of resistance to all races of *Rhizoctonia* sp. (*44*).

Cottonseed and seedlings must be protected from infection. There are three main control measures that should be practiced to reduce losses from cotton seedling diseases. These are: the use of high quality cottonseed, seed treatment, and soil treatment. Each of these will be discussed separately and in detail.

A. Seed Quality

"High quality seed" refers to cottonseed that are genetically pure and free of inert matter, weed seed, damage, and seed-borne disease organisms. The term is used also to define the ability of cottonseed to give a stand of vigorous, healthy cotton seedlings even under adverse conditions for germination and emergence (*6, 7*). High quality seed are more tolerant to low temperatures and less susceptible to attacks by soil-borne pathogenic organisms (*7*). Annotated bibliographies on seed storage and deterioration have been published (*16, 17*).

Poor quality seed have reduced germination rates and result in spotty, uneven stands, with weak seedlings and plants that are more susceptible to disease, insect damage, and adverse weather conditions (see Section IV). Deterioration of the embryo root within cottonseed also is the principal cause of nubroot (*57*). Poor quality cottonseed can be the result of deterioration either in the field or in storage where improper temperatures and humidity levels cause deleterious chemical changes in the seed.

Primary factors affecting cottonseed deterioration in the field are high moisture and delayed harvest. Defoliation is desirable when cotton is rank or boll rot is excessive. Several practices will preserve cottonseed quality between harvest and ginning. Only dry seed cotton should be harvested, but if wet cotton is harvested, it should be ginned immediately. Damp seed cotton should not be force-packed in trailers. Wire mesh or open-walled trailers provide air circulation required to reduce cottonseed deterioration in damp or wet cotton.

The primary factors affecting cottonseed deterioration in storage are: temperature and humidity within the seed, length of storage, infestation with microorganisms, and air permeability of bulk seed. Other factors are: external humidity and temperature and the extent of preharvest seed deterioration (*6, 7*). Cottonseed should be stored in dry conditions to maintain a 10 per cent moisture content of the seed.

Partially deteriorated cottonseed may germinate well during standard germination tests in the laboratory but result in a poor stand in the field. Per cent germination tests should be run as close to planting time as is feasible.

Germination tests often are not sufficient to determine the extent to which cottonseed have deteriorated or the stand that can be expected from the seed. Dual temperature germination tests and/or tests measuring the resistance to the passage of electric current through water containing cottonseed can be used to determine more precisely the extent of seed deterioration and infection by pathogenic organisms (*6, 7*).

Only the highest quality seed available should be planted. If high quality seed is not available, it has been reported in Mississippi that calcium as a seed treatment was beneficial to weak seedlings developed from partially deteriorated seed (*58*).

B. Seed Treatment

Seed treatment involves various techniques and/or chemicals for controlling disease-causing organisms that attack propagative stocks, seed, and seedlings. Seed treatment is the most important and most economical method of controlling certain seedling diseases. For some seed- and soil-borne diseases, seed treatment is the only means of control (*48, 49, 50*).

One of the most critical periods of plant growth and development is from seed germination to independent establishment of the seedling. It is during this period that young cotton plants are most susceptible to disease-causing organisms that incite seed rot, damping-off, stem blight, and root rot. Treatment of cottonseed controls not only these disease-causing organisms but also other organisms whose symptoms may not appear until the plant is near maturation. The anthracnose and bacterial blight pathogens are good examples of this latter type.

A wide range of organisms cause diseases of cottonseed and seedlings, including bacteria, fungi, nematodes (*38*), and insects (*26*). Bacteria and fungi are found either on the outside or inside of cottonseed. A seed is said to be *infested* when disease organisms are carried on the outside of seed. If the seed has pathogens established under the seed coat or in seed tissues, it is *infected.* It follows that a method or material found to kill or mitigate the pathogen on the outside of the seed would be called a *disinfestant* and would be used to disinfest the seed. On the other hand, a *disinfectant* would be used to disinfect the seed. Cottonseed may be free of disease-causing organisms but still be subject to attack by pathogens in the soil. Seed treatment materials used to protect seed from these pathogens are called *protectants,* or protective materials.

To control disease-causing organisms infecting seed without killing the seed is a delicate problem. Two methods have proved effective. One uses hot water and the other requires the use of volatile fungicides, such as formaldehyde. Seed treated by either of these methods, however, are not protected from soil-borne pathogens and must be treated, in addition, with a protectant-type seed treatment before planting.

Practically all effective cottonseed treatment materials are disinfectants and many, in addition, have protective qualities. These materials may come in the form of a dust, powder, or liquid. These types of seed treatment materials are most familiar and are widely used for cottonseed treatment.

Seed treatment is not a substitute for high quality seed. Generally, poor quality cottonseed receive more benefits from seed treatment than good quality seed, in that, poor quality seed that might not survive are given a chance to grow.

Seed treatment cannot improve environmental conditions. Unless soil temperatures and moisture are good for germination, no amount of seed treatment material will help.

The Louisiana Agricultural Experiment Station cooperates with the Cotton Disease Council in the regional cottonseed treatment tests. Each year a large number of new seed treatment chemicals are compared with certain standards and with nontreated seed. The tests are planted in randomized, replicated blocks with 25 hills for each seed treatment. Each hill is planted with five seed. Stand counts and field data are collected and analyzed (Table 5). From these tests cottonseed treatment materials and rates for Louisiana are suggested (Table 6).

C. Soil Treatment

High quality seed and seed treatment help produce an even, desirable stand of cotton at the first planting. However, these practices are

TABLE 5.—Means for number of cotton seedlings per acre (stand) and yield of seed cotton per acre from regional seed treatment tests on reginned cottonseed, for treatment, rate in ounces per 100 pounds of seed, and year indicated at Northeast Louisiana Agricultural Experiment Station, St. Joseph. (A portion of the data for each year of four years is reported.)

		1961		1962		1963		1964	
Treatment	Rate	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Nontreated	....	43	2,620	18	1,498	43	3,254	55	1,647
Captan 75	1.5	36	1,741						
	3.0	43	2,521						
Ortho LM	3.0	48	3,265*						
Ceresan L	2.0	60	2,902*						
	3.0	46	3,047*	29*	2,387	63	3,450	62	1,647
Ceresan M	3.0	46	2,920*	38*	2,422	58	3,620*	67*	1,634
Chipcote 25	1.0			37*	2,631				
	1.5			30*	2,701				
Chipcote 75	2.0			18	2,526				
	3.0			25*	2,178				
Dexon	3.0			25*	2,091	46	2,927		
Elcide 70	2.0	50	3,319*	19	1,934				
	3.0			22*	1,777				
Gallatox	3.0							52	2,208
Isobac 20	8.0					41	2,914	55	1,816
3M-AR990A	1.0			22*	2,352	46	3,502*		
	2.0			22*	2,091	40	3,385		
Panogen 15	2.0	50	3,011*						
	3.0	52	2,939*	25*	2,126	62	3,332	65*	1,803
PCNB + captan	4+3	50	2,630	34*	2,544				
PCNB + Ceresan M	4+3	58	3,174*	38*	2,526			77*	1,464
PCNB+ Dexon	4+3	50	3,011*	38*	2,718				
PCNB + Panogen 15	4+3	52	2,830*	34*	2,317	63	4,090*	63	2,104
PCNB + OM-2424	4+3							81*	1,647
LSD at .05 level		NS	60	4	NS	NS	234	10	NS

*Significant at .05 level.

TABLE 6.—Suggested cottonseed treatment guide for Louisiana

Fungicide	Manufacturer or company	Ounces per 100 pounds	
		Machine-delinted	Acid-delinted
Agrox	Chipman Co.	4.0	3.0
Captan 75	Stauffer Chem. Co.	3.0	2.0
Orthocide LM	Calif. Chem. Co.	3.0	2.0
Ceresan L	DuPont	3.0	2.0
Ceresan M	DuPont	3.0	2.0
Chipcote 25	Chipman Chem. Co.	2.0	2.0
Chipcote 75	Chipman Chem. Co.	3.0	3.0
Elcide 70	Eli Lilly	3.0	2.0
Panogen 15	Morton Co.	3.0	2.0
PCNB 75 + Captan 75	Several companies	4.0+3.0	4.0+2.0
PCNB 75 + Ceresan L	Several companies	4.0+3.0	4.0+2.0
PCNB 75 + Panogen 15	Several companies	4.0+3.0	4.0+3.0

not enough to hold a uniform stand in areas where soil-borne pathogens and environmental conditions are favorable for disease development. To maintain a uniform stand of cotton, soil-borne pathogens must be controlled. Control of pre- and post-emergence damping-off and root rot is accomplished by fungicidal treatment of soil that surrounds seed (*4, 5, 21, 28, 29, 32, 34, 35, 36, 41, 45, 46, 47, 57*). There are four ways in which soil fungicides can be incorporated into the soil at the time of planting (Fig. 4). These are: hopper-box method, in-the-furrow spray, in-the-furrow dust, and use of granular applicators. Each method will be discussed separately. The acreage treated with soil fungicides in Louisiana ranged from 13 to 18 per cent between 1961 and 1964 (Table 2).

Hopper-box Method

Application of soil fungicides by the hopper-box method has been studied for several years in Louisiana (*28, 29, 47, 49*). This method

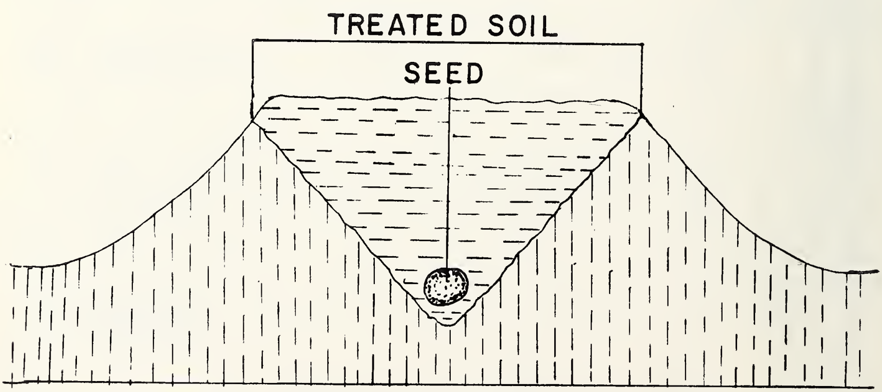

FIGURE 4.—Ideal placement of a soil fungicide around cottonseed at the time of planting for controlling cotton seedling diseases.

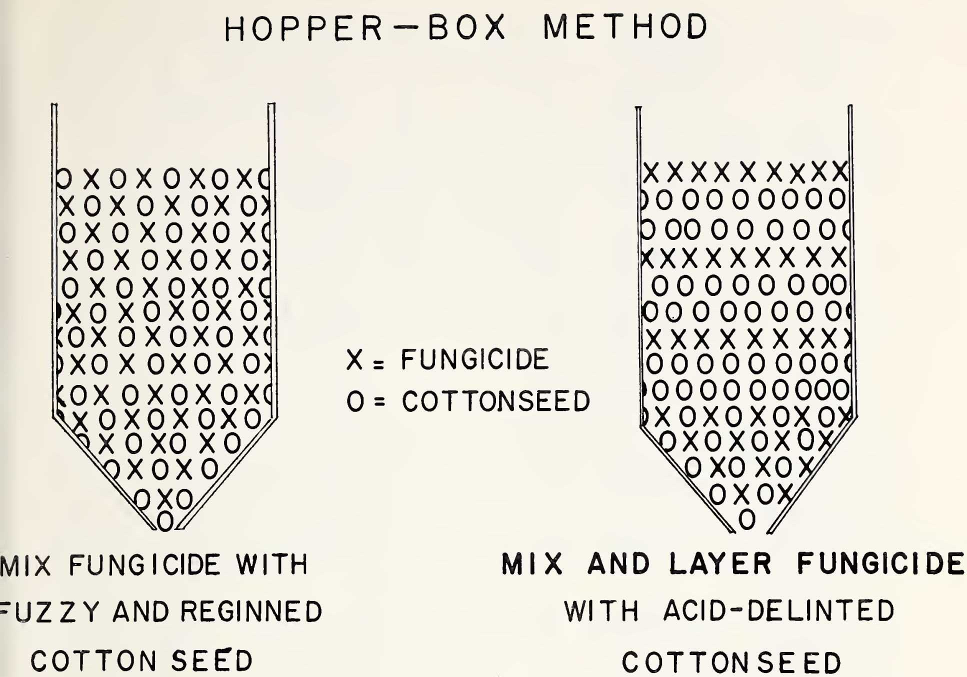

FIGURE 5.—A hopper-box method of applying soil fungicides at the time of planting for controlling cotton seedling diseases. The manner in which the fungicide is mixed with cottonseed depends on whether or not acid-delinted seed are used.

requires that fungicides be mixed with cottonseed either before the seed are placed in the hopper-box or during the planting operation, depending on whether acid-delinted or reginned seed are used (Fig. 5). When reginned seed are used, fungicide and seed should be thoroughly mixed in a separate container. This mixture then is placed in the hopper-box for planting.

Although not recommended for acid-delinted seed, this method can be used for such seed but special handling is then required. Fungicides do not adhere readily to the smooth surface of acid-delinted seed, and consequently they tend to accumulate, during the planting operation, at the bottom of the seed hopper. This disadvantage can be overcome either by adding fungicide to the seed as needed during the planting operation or by placing a layer of seed mixed with fungicide in the bottom of the seed hopper, then a layer of seed without fungicide, followed by a layer of fungicide. This layering is repeated once or twice, depending on the height of the hopper box (Fig. 5).

A large number of fungicides, alone or in combination, have been evaluated for their effectiveness in controlling cotton seedling diseases

TABLE 7.—Means for number of cotton seedlings per acre (stand) and yield of seed cotton per acre with various soil fungicides at a rate of three pounds per bushel of seed, using the hopper-box method of application, for year and location indicated. (These data represent portions of larger experiments.)

Fungicide	Per cent active ingredient	1961 Curtis	1961 St. Joseph		1962 Curtis		1962 St. Joseph		1963 Curtis		1963 St. Joseph		1964 Curtis		1964 St. Joseph	
		Stand	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Nontreated check		60,250	58,750	2,806	39,750	1,303	28,500	2,795	22,750	1,313	59,500	1,943	57,500	916	25,500	2,813
PCNB	15						36,250*	2,546	35,500*	1,372	56,000	1,998				
PCNB + captan	10-10	59,500	52,500	2,556	26,000	1,168	43,750*	2,860*	35,750*	1,310	65,750	1,958	54,750	811	28,750	2,705
PCNB + OM-2424	10-10				29,000	1,331	51,750*	2,948	37,750*	1,347	62,750	2,118	61,250	720	30,500	2,750
PCNB + maneb	10-10	66,500*			39,750	1,313	41,000*	2,628								
PCNB + M45	10-10												60,250	739	29,500	2,745
PCNB + thiram S-42	10-10				32,250	1,336	41,750*	2,824*	32,250*	1,262	57,500	1,805	57,750	909	26,750	2,735
OM-2424	10								33,500*	1,305	68,000	2,218	61,250	706	31,000	2,775
Nabac + captan	3-7	41,750			40,000	1,491*	61,000*	3,180*	30,250*	1,413	66,000	1,873	49,250	712	28,000	2,680
Dexon + 2635	2.5-10				23,750	926			29,500*	1,190			59,250	981	31,750	2,590
LSD at .05 level		3,750	NS	NS	750	118	1,250	11	6,750	NS	NS	NS	6,900	NS	NS	45

*Significant at .05 level.

when applied by the hopper-box method (*28, 29, 47, 49*). Selected data from 4-year results are presented in Table 7. Suggestions for materials to be used in Louisiana are based on these and other results (Tables 7, 8, 12, 13, 14, 15, 16, 17).

In 1962, 1963, and 1964, regional soil treatment tests were conducted in cooperation with the Cotton Disease Council. The same fungicides, seed source, and method of application were used in all tests. The results of these tests are presented in Table 8.

Results indicated that a combination of fungicides must be used for best control. PCNB in combination with other fungicides such as captan, maneb, thiram, dexon, or OM-2424 is most effective. Other materials that show promise are OM-2424 used alone, or a combination of PCNB plus folpet.

For the hopper-box method, use the rate of fungicide suggested on the label. In general, soil fungicides are mixed with cottonseed at a rate of 1 pound of fungicide to 10 pounds of seed, with a minimum application of 3 pounds of fungicide per acre (Table 17). When fungicides are mixed with the seed, it is necessary to recalibrate the planter to the desired seeding rate because many fungicides tend to reduce the seeding rate (Table 9).

The hopper-box method is the easiest and quickest to use. The method, however, is the least efficient of the four methods, and gives only reasonably desirable distribution of fungicide and protection. It cannot be used where it is desirable to plant cottonseed more than an inch in depth. Fungicides tend to concentrate toward the bottom of the hopper-box because of agitation and settling of the fungicide during the planting operation. The first seed planted, therefore, will tend to have more fungicide than the last. Some planters do not adapt well to this method and become clogged.

In-the-Furrow Spray Method

This method is more effective than the hopper-box method and involves the use of an adapted low-pressure insecticide or herbicide sprayer operated by a pump from the power take-off (Fig. 6). Hoses lead from the pump to ¼-inch pipes about 10-15 inches long fitted with two spray nozzles per row. The first nozzle should be centered on the furrow so that the spray strikes the soil around the seed and 3 inches on each side of the seed furrow. Optimum height of the front nozzle is 1½—3 inches above the original soil surface. The rear nozzle should be directed to spray soil as it is tumbled into the seed furrow, with a small fraction of the spray to strike the top of the covered row. Nozzles to use and suggested pressures are given in Table 10. A method for accurately determining planting speed in miles per hour in order to select proper nozzle tips is given in Table 11.

From 1960 to 1964 a large number of soil fungicides were evaluated

TABLE 8.—Means for number of plants per acre (stand) and yield of seed cotton per acre with various soil fungicides at a rate of three pounds per bushel of seed, using the hopper-box method of application, for year and location indicated. (These data are part of the cooperative regional soil treatment tests.)

	Per cent	1962			1963				1964	
	active	Curtis	St. Joseph		Curtis		St. Joseph		St. Joseph	
Fungicide	ingredient	Stand	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Nontreated check		32,750	29,750	2,795	22,750	1,313	59,500	1,943	25,500	2,813
PCNB	15	34,250	32,250*	2,546	35,500*	1,372	56,000	1,998		
PCNB + captan	10-10	50,250	43,750*	2,860*	35,750*	1,310	65,750	1,958	28,750	2,705
PCNB + maneb	10-10	40,250	41,000*	2,628						
PCNB + thiram	10-10	33,750	41,750*	2,824*	32,250*	1,262	57,500	1,805	26,750	2,735
PCNB + OM-2424	10-10				37,750*	1,347	62,750	2,118	30,500	2,750
Nabac + captan	3-7	40,000	51,000*	3,180	30,250*	1,413	66,000	1,873	28,000	2,680
OM-2424	10				33,500*	1,305	68,000	2,218	31,000	2,775
LSD at .05 level		NS	1,250	11	6,750	NS	NS	NS	NS	45

*Significant at .05 level.

TABLE 9.—Effect on seeding rate of mixing various fungicides with cottonseed, using the hopper-box method of application for two field experiments, 1964

Fungicide	Per cent active ingredient	Per cent seed planted in 800 row feet	
		Experiment number	
		1	2
PCNB + captan	10 + 10	25	33
PCNB + M-45	10 + 10	22	27
Nabac + captan	.75 + 7	22	27
PCNB + thiram S-22	10 + 10	22	27
PCNB + OM-2424	10 + 10	..	24

for their effectiveness in controlling cotton seedling diseases by the in-the-furrow spray method (*28, 29, 47, 49*). Selected data from these tests are presented in Table 12. Suggestions for materials to be used in Louisiana are based on these and other results (Tables 12, 13, 14, 15, 16).

Results indicated that PCNB in combination with other fungicides gave best results. An increase in rate of fungicide over that used for the hopper-box method is required, because a greater amount of soil is treated. Read package labels for specific rates of material to be used. In general, a rate of 10 pounds of formulated material per acre is required (Table 17). Use only fungicide in emulsifiable concentrate or wettable powder form. Dusts used for the hopper-box and dust methods are not satisfactory.

In 1961, a series of tests were conducted to determine if soil fungicides might be effective in controlling cotton seedling diseases when applied to the soil surface alone or in combination with a herbicide, diuron. Results indicated that this method was of little value (Table 13).

The in-the-furrow spray method has proved to be more effective than the hopper-box method (Tables 14, 15). Advantages are that the fungicide distributes better in the soil, the method can be used where seed are planted below one inch, either acid-delinted or reginned seed can be used, and there is no clogging of the planter.

The disadvantages of this method are the necessity of having to stop and refill tanks with water plus fungicide during the planting operation, and competition for use of the power take-off if a grower wishes to apply a pre-emergence herbicide at the time of planting. The latter problem can be solved by using a special two-pump system on the power take-off to operate both spray systems.

In-the-Furrow Dust Method

This method involves the mixing of soil and fungicides by using a low air velocity duster (Fig. 7) that blows dust through special distribution tubes or shoes (Fig. 7F) located at a point or points between the furrow opening and closing apparatus (Fig. 7C, D, E). A suitable rig,

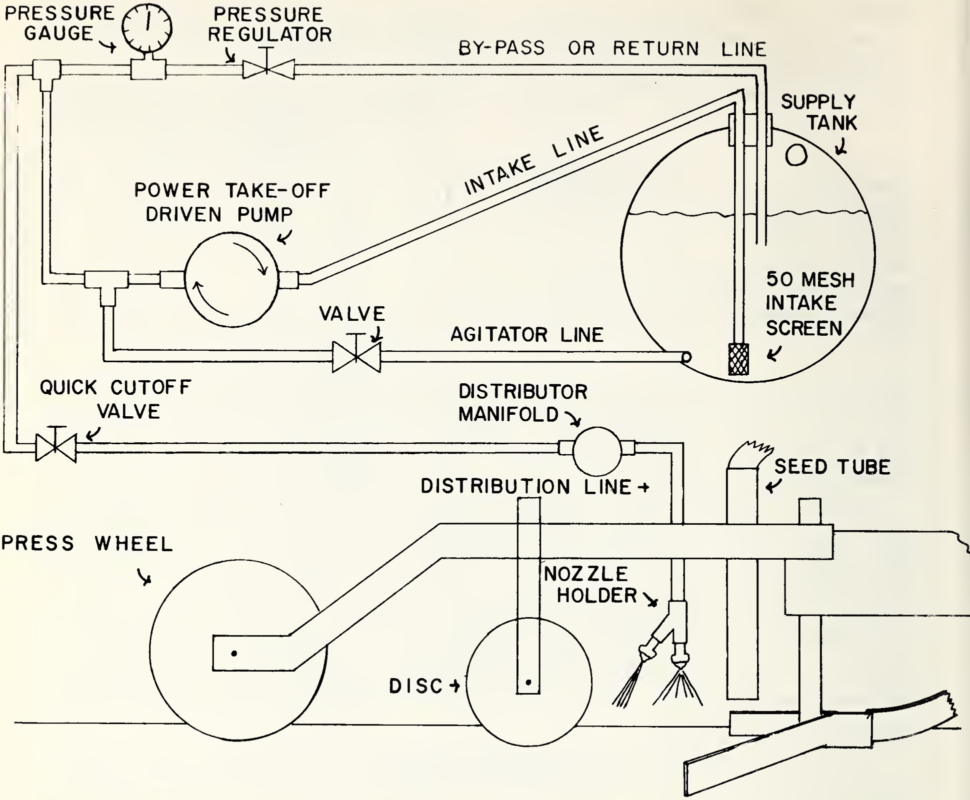

FIGURE 6.—Suggested apparatus for in-the-furrow spray application of soil fungicides at the time of planting for controlling cotton seedling diseases.

which can be attached to a planting rig or tractor, called a "Chem-Soil Mixer" (Gustafson Mfg. Co., Corpus Christi, Texas) can be used and is suggested. Special distribution tubes and shoes are available. This apparatus can be operated from the power take-off (Fig. 7B) or by an auxillary gas engine (Fig. 7A).

The mixing of soil and fungicide by this method was studied and found to give better results than either hopper-box or in-the-furrow spray methods (Tables 14, 15, 16). Dusts containing Terraclor (PCNB) plus other fungicides such as captan, maneb, thiram, and dichlone are suggested for use with this method.

Dusts are applied at a rate of 10-15 pounds per acre and should contain the suggested amounts of active fungicides for adequate treatment (Table 17). Follow instructions on the container recommended by the manufacturer.

In-the-furrow dust equipment has been used successfully in Texas

TABLE 10.—Suggested single or combination Tee Jet Nozzle tips (40 p.s.i.) (From Olin Mathieson Chemical Corporation Publication AD-1160-161.)

Planting Speed	10 gal./Acre	15 gal./Acre
	Two Nozzles per Row	
3.0 MPH	2—¼ TT X6	1—¼ TT X6 1—¼ TT 6502
3.5	1—¼ TT X6 1—¼ TT X6	1—¼ TT X8 1—¼ TT 6502
4.0	2—¼ TT X8	1—¼ TT X10 1—¼ TT 6503
4.5	1—¼ TT X8 1—¼ TT X10	1—¼ TT X10 1—¼ TT 6503
5.0	2—¼ TT X10	1—¼ TT X10 1—¼ TT X20
	(Use 50-mesh screens)	
	One Nozzle per Row	
3.0 MPH	¼ T X12	¼ T X18
3.5	¼ T X14	¼ T X20
4.0	¼ T X16	¼ T X24 or
4.5	¼ T X18	¼ T 6504
	12 gal./Acre ¼ T X26	
	(Use 50-mesh screens)	

TT = Male Connection.
T = Female Connection.

for a number of years. It is particularly adapted to lighter soils and large acreages. The initial cost for equipment is greater than that used for other methods. Seed can be planted below one inch. Since a greater amount of soil is treated than with the hopper-box method, a larger amount of fungicide is required per acre.

Use of Granular Applicator

Some recent work at other experiment stations has shown that fungicides in granular form might be applied by using any gravity-flow type of granular applicator similar to those used for the application of granular fertilizers and insecticides. The granules are metered through a distribution tube, which should be placed between the seed drop tube and covering discs. The results of these experiments indicate that more work has to be completed before suggestions can be made.

TABLE 11.—A method for accurately determining planting speed in miles per hour in order to select proper nozzle tips (From Olin Mathieson Chemical Corporation Publication AD-1160-161.)

1. After setting planter and starting tractor on a straight course, use proper gear and throttle to attain normal planting speed.
2. After normal planting speed is attained, drop one object off the tractor to mark a starting point. Exactly 30 seconds later, drop a second object off the tractor. (If two people are available, the second person can time and mark the starting and stopping point.)
3. Measure the distance between the two objects in feet.
4. Obtain tractor speed from the following table:

Distance travelled in 30 Seconds	Tractor Speed
132 feet	3.0 MPH
143	3.25
154	3.5
165	3.75
176	4.0
187	4.25
198	4.5
209	4.75
220	5.0

Individual growers may wish to try the application of granular fungicides on a limited basis until Experiment Station recommendations are available. Instructions provided by the manufacturer or county agents should be followed.

Advantages in using granular application of fungicide are: easy handling; the applicator can work off the drives on a planter; and the equipment is relatively less expensive than that needed for in-the-furrow sprays and dusts.

Materials to Use

The use of soil fungicides in Louisiana has been limited (Table 2). About 15 per cent of affected acres have been treated with soil fungicides from year to year. There are a number of labeled products on the market. In greenhouse and field tests (Tables 3, 7, 8, 12, 13, 14, 15, 16) over the past eight years a number of materials, alone or in combination, have proved effective in controlling post-emergence seedling damage caused by soil-borne organisms. When compared to other materials, PCNB alone or in combination with either captan, maneb, thiram, dichlone, dexon, or OM-2424 has given good results (Tables 3, 7, 8, 12, 13, 14, 15, 16). PCNB plus OM-2424 has shown the most promise.

The fungicides suggested for soil treatment are available under a number of trade names and labels. Container labels should be read carefully noting fungicides included and their per cent active ingredient. PCNB is known commercially as Terraclor; captan as either Captan or Orthrocide; maneb as either Manzate or Dithane; dichlone as Phygon; thiram as Thylate; and folpet as Phaltan.

TABLE 12.—Means for number of plants per acre (stand) and yield of seed cotton per acre with various soil fungicides at rates of five pounds per acre for powders and one to four quarts per acre for liquids applied as in-the-furrow sprays for year indicated. (These data represent portions of larger experiments.)

	Per cent	1960	1961	1962				1963				1964			
	active	Curtis	Curtis	Curtis		St. Joseph		Curtis		St. Joseph		Curtis		St. Joseph	
Fungicide	ingredient	Stand	Stand	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Check		83,800	57,250	33,750	1,609	37,250	3,202	25,750	1,060	59,500	1,943	57,500	916	25,500	2,813
PCNB-EC			79,000*	31,500	1,664							64,500*	1,125		
PCNB + captan	10-10	153,750*	57,250	44,250	1,853*										
PCNB + dichlone	10-10	147,500*													
PCNB + dexon	35-35	141,750*	55,500												
PCNB + OM-2424	10-10			40,750	1,671	40,750*	2,962	42,750*	1,155*	78,750*	2,080	67,000*	1,092	35,000*	2,698
PCNB + maneb	10-10			36,500	1,687*										
PCNB + thiram	10-10			40,000	1,723*										
PCNB +126B				38,500	1,586									26,500	2,798
Thiram	50	114,500*						39,000*	1,246*						
OM-2424 EC								38,750*	1,262*						
Nabac	25							33,750*	1,246*						
LSD at .05 level		10,000	4,250	NS	78	2,500	NS	5,250	60	11,250	NS	2,929	NS	4,600	NS

*Significant at .05 level.

TABLE 13.—Means for number of plants in 52 feet of row from soil whose surface was sprayed with various soil fungicides either in combination with diuron or without at rates of either four quarts per acre for liquids or five pounds per acre for powders at location indicated

	Fungicide, location and use of diuron				
	Baton Rouge			St. Joseph	
Fungicide 4 qts./A.	With diuron	Without diuron	Fungicide 5 lbs./A.	With diuron	Without diuron
Nontreated check	127	153	Nontreated check	174	150
PCNB EC	136	149	PCNB + captan 10-10	183	196*
Thiram EC	152	157	PCNB + folpet 10-10	187	166*
Dow Zectran	158	152	PCNB + maneb 10-10	185	183*
Tin-San	163	149	PCNB + thiram 10-10	186	201*
Quick-San	149	148	Nabac 25	187	153*
5961	150	159	Nabac + captan 10-10	173	182*
LSD_{05}	NS	NS	LSD_{05}	NS	13

*Significant at .05 level.

A grower may wish to try one or more of these materials on a small part of his land for experimental purposes. It should be remembered that materials that work well as a liquid or dust may not give the same response when used in the hopper-box. Suggested materials to use and rate based on the method of application are given in Table 17.

Cost of Materials

The spray and dust methods give better control than the hopper-box method but require additional equipment and more fungicide per acre because more soil is treated when they are used. Spray and dust methods of applying soil fungicides, therefore, are a little more costly than the hopper-box method. Stand increases of about 20 to 25 per cent are obtained at a cost of about $3.50 to $5.00 per acre depending on method and material used. These costs for all three methods are based on a mixture of two soil fungicides.

The use and application of soil fungicides must be thought out in view of costs and results. Working with the county agent, the grower should decide if he has a seedling disease problem and if so, how he can best control it. The control method must be worked into the grower's present program of fertilizer application, weed control, and nematode control. Later planting, rather than the use of soil fungicides, may give seedling disease control and should be considered.

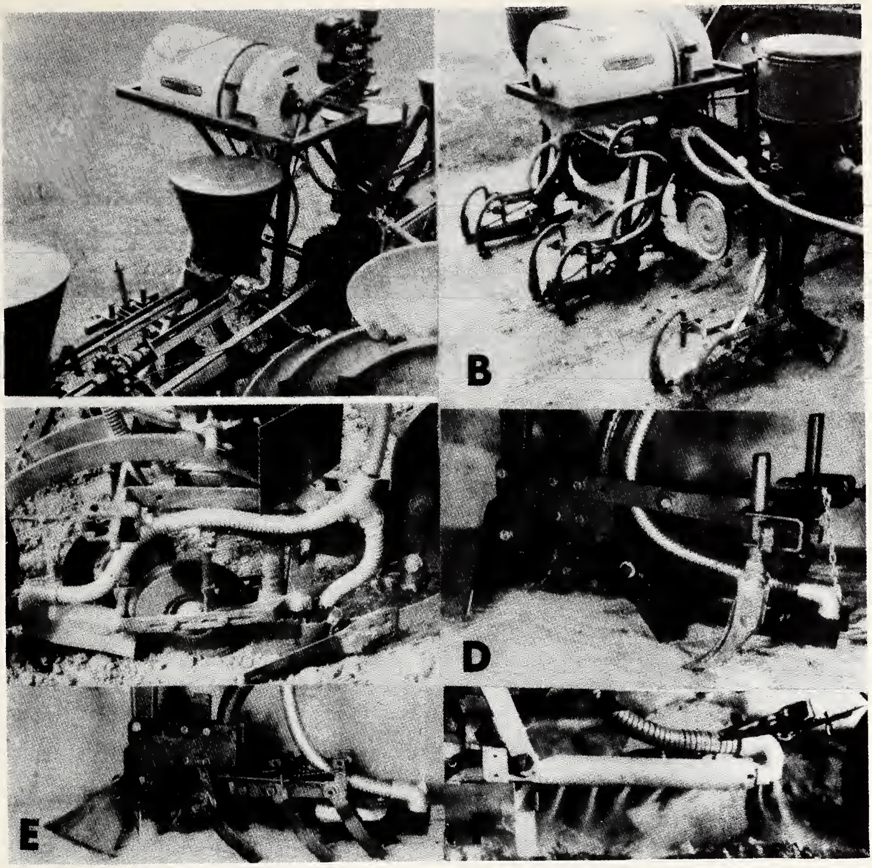

FIGURE 7.—Equipment for in-the-furrow dust application of soil fungicides. A. Side view showing engine-powered arrangement. B. Side view showing attachment to power take-off. C. Showing attachments for use with seed embedding wheels. D. and E. Showing attachments for other covering devices. F. Dust pattern from special attachment. (From Olin Mathieson Chemical Corporation Publication AD-1160-161.)

IV. Effect of Environment and Other Factors on Cotton Seedling Diseases

Environmental conditions determine the extent of soreshin development in any one area. Conditions favorable for the disease may occur one year but not the next. Any condition that is unfavorable for development of the cotton seedling and favorable to the pathogen makes cotton more susceptible to seedling diseases (*19*). Some growers have a long

TABLE 14.—Means for number of plants per acre with various soil fungicides applied by three methods. (A portion of a larger experiment is given.)

Fungicide	Per cent active ingredient	Method and rate: In-the-furrow spray, 4 qts./A. Curtis	Hopper-box, 3 lbs./bu. Curtis	Hopper-box, 3 lbs./bu. St. Joseph	In-the-furrow dust, 5 lbs./A. St. Joseph
Nontreated check		57,250	60,250	58,750	58,750
PCNB + captan	10-10	57,250	59,500	56,250	52,500
PCNB + maneb	10-10		66,500*		
Nabac	25	39,000		45,500	
Nabac + captan	10-10		41,750		64,750
PCNB + folpet	10-10	56,750			
2635	70		12,750		66,250
3944	2		55,250		63,750
PCNB + dexon	35-35	55,500			
PCNB + dichlone	10-10	61,750			
LSD at .05 level		4,250	3,750	NS	NS

*Significant at .05 level.

TABLE 15.—Means for number of plants per acre with various soil fungicides applied by three methods. (A portion of a larger experiment is given.)

Fungicide	Per cent active ingredient	Method and rate of application: Hopper-box, 3 lbs./bu.	Dust, 10 lbs./A.	Spray, 10 lbs./A.
Nontreated check		84,000	84,000	84,000
PCNB + captan	10-10	111,750	133,000*	153,750*
PCNB + dichlone	10-10	37,750	134,500*	147,500*
PCNB + thiram	10-10		154,500*	
PCNB + dexon	35-35	115,000	71,000	141,750*
LSD at .05 level		35,500	11,250	10,000

*Significant at .05 level.

TABLE 16.—Means for number of plants per acre with various soil fungicides applied by three methods at Red River Valley Agricultural Experiment Station, Curtis

Fungicide	Per cent active ingredient	Method, rate, and experiment number: Hopper-box, 3 lbs./bu. 1	Hopper-box, 3 lbs./bu. 2	Spray, 10 lbs./A. 1	Spray, 10 lbs./A. 2	Dust, 10 lbs./A. 1	Dust, 10 lbs./A. 2
Nontreated check		84,000	28,500	84,000	57,250	84,000	21,750
PCNB + captan	10-10	121,750	44,500*	153,750*	57,250	133,000*	34,750
PCNB + dexon	35-35	115,000	21,250	141,750*		71,000	59,000
PCNB + dichlone	10-10	37,750	58,250*	147,500*	61,750*	134,500*	43,250
PCNB	EC				79,000*		
LSD at .05 level		NS	4,250	10,000	4,250	11,250	NS

*Significant at .05 level.

TABLE 17.—Suggested* fungicides and rates in pounds per acre for use as a soil treatment to control cotton seedling diseases, based on method of application to be used

Fungicide	Per cent active ingredient	Minimum and maximum rates in pounds or pints per acre for use with: Hopper box	Spray method	Dust method
PCNB + captan	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + thiram	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + maneb	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + OM-2424	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + polyram	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + folpet	10-10	3 – 5 lbs.	5 – 10 lbs.	10 – 15 lbs.
PCNB + captan EC			2 – 4 pts.	
PCNB + thiram EC			2 – 4 pts.	
PCNB + OM-2424 EC			2 – 4 pts.	
PCNB + 126B EC			2 – 4 pts.	
Lanstan EC			2 – 4 pts.	

*Follow directions on container labels.

history of seedling disease in certain areas of their fields and not in others. These differences are due to environmental conditions.

Temperature and Moisture — Temperature and moisture are the two most critical conditions for seedling disease development. Of these, temperature has the greater effect (*56*). Studies under both greenhouse and field conditions have been made at various institutions on the effect of soil temperature and moisture on the development of soreshin (*2, 9, 12, 13, 14, 24, 30, 40, 41, 56*). Personnel of the Louisiana Agricultural Experiment Station have made a 4-year study on the effect of soil temperature on cotton emergence and seedling diseases, and a report of the study is to be published shortly.

Temperature plays an important role in the time required for cotton seeds to germinate and the seedlings to emerge (*4, 20, 40*). The minimum temperature for the germination of high quality upland cottonseed is 53° F. (*20*), with the optimum at 85° - 95° F. (*40*).

In Arizona (*21*) and the mid-South (*40*) a temperature of 65° F. or above was found to be necessary for good seedling growth.

In Texas high quality seed can be planted when the soil temperature at 8-inch depth has a 10-day average of 65° F. (*13*).

Rhizoctonia solani can grow over a relatively wide temperature ranging from 41° to 91° F. (*39*). The fungus can infect cotton over a range of temperatures, with an optimum of 63° - 73° F. (*1, 2, 56*). It has been shown that soil temperature is one of the more important factors affecting the capacity of various isolates of *R. solani* to infect cotton seedlings (*9, 14, 33, 42*).

Other Factors — Among other factors that can aggravate or be confused with cotton seedling diseases are: cottonseed deterioration (7);

excess nitrogen (*55*); plant parasitic nematodes (*27, 38*); insect infestations (*26*); calcium deficiency (*58*); combined soil chemicals (*11, 37*); and mechanical injuries (*21*).

The cause and control of cottonseed deterioration and its influence on cotton seedling disease has been discussed.

When nitrate nitrogen reaches a concentration of over 300 ppm in the soil about a cotton plant, delayed germination, injury, or retarded growth may occur. When concentrations are increased, the amount of injury increases. To avoid this injury, nitrate nitrogen should be drilled into the soil about 6 inches to the side of the seed drill (*55*).

A number of experiments have shown that in certain soils where nematode infestations were high, the incidence and severity of soreshin were greater than where nematode infestation was low (*27, 38*). Chemicals for control of nematodes should be used only after it has been established, through soil analysis, that a nematode problem exists.

Where thrip infestations were severe, young cotton plants became more susceptible to seedling diseases (*26*).

Calcium deficiency on cotton seedlings can cause symptoms that appear similar to those of seedling root rot, and pre- and post-emergence damping-off. Calcium deficiency seems to be most severe after heavy rains on light, sandy soils when high temperature and light intensity are coupled with moderately cool, night temperatures (*58*).

Cotton seedlings that were injured by some mechanical means, such as hail, farm equipment, and sand-blasting, tended to be more susceptible to seedling diseases (*21*). Mechanical injuries should be avoided wherever possible.

In recent years observations have shown that certain systemic insecticides used in conjunction with certain fungicides and/or herbicides and under certain environmental conditions, result in seedling diseases more severe than where no chemical was used or where each was used alone (*1*). The use of certain soil fungicides will help to reduce losses where a combination of herbicide and insecticide is used (*11, 37*). Consult specialists before multiple soil chemical applications are attempted.

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